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Title: **METHOD AND ARRANGEMENT FOR THE CONTACTLESS AXIAL MEASUREMENT OF MOTOR VEHICLES**

METHOD AND ARRANGEMENT FOR THE CONTACTLESS AXIAL MEASUREMENT OF MOTOR VEHICLES

Area of Application of the Invention

The invention is in the field of diagnosing motor vehicles and is to be used for measuring the geometry of wheel axles and of the steering.

Technical Background

An accurate adjustment of the wheel axles, particularly of the front axles, is of decisive importance for driving motor vehicles safely and in comfort. This adjustment should be checked regularly by measurement. For this purpose, known measuring equipment is available, with which the wheel camber, toe-in, caster, kingpin angle, track difference angle and steering roller diameter are measured. These parameters are given essentially by the spatial position of the wheel suspension (steering axle) relative to the wheel plane or to vertical or horizontal reference planes.

The measuring equipment required for determining said parameters is based on mechanical, optical, optical-mechanical or electronic methods ("Wissen-schaftliche Zeitschrift" of the Technical University of Dresden, 1968, pages 923 - 941, "Werkstattechnik", 1979, pages 12 - 14, "Krafthand", 1979, page 608). Optical equip-ment is generally used for the measurements. This equipment works with a mirror, which is adjusted on the respective wheel axle. For evaluating the results of the measurement automatically, it is known that the light beam, directed onto the mirror, may be reflected onto the light-sensitive layer of video recording equipment. By evaluating the video signal, the position of the image point is determined and, with that, the desired measurement signal obtained (German Offenlegungsschrift 23 53 965).

Moreover, it is generally known that video signals may be evaluated electronically in order to automate measurement and control processes. For example, measuring video systems, which work in the visible, infrared or ultraviolet region of the spectrum, can be used for measuring length, width and height, for determining the position of objects at rest or for identifying and measuring one or several points with a certain brightness level. Complicated

conversions by means of a microcomputer, equipped with several microprocessors or in conjunction with a mainframe computer are also possible here. Linking the measurement process to such computer operations is necessary, for example, if three-dimensional processes are to be determined. This is possible with the help of two video cameras, the signals of the two video cameras being evaluated according to the rules of trigonometry (promotional brochure "Messende TV-Systeme" (Measuring Video Systems) of the Hammamatsu Company).

Presentation of the Invention

a) Objective

It is an object of the invention to provide a method and an arrangement for measuring wheel axle and steering geometry data of a motor vehicle; this method and the arrangement are to make it possible to obtain a contactless and adjustment-free measurement and a fully automatic display of the data.

b) Summary of the Invention

This objective is accomplished starting out from a method, for which an image, which depends on the position of the wheel, is produced on the light-sensitive layer of a video camera tube and the image produced is evaluated electronically. Pursuant to the invention, the following steps are provided for the method of measurement:

a. an elliptical image of the circle assigned to the outer wheel rim diameter of each wheel or a circle, which is disposed concentrically to the former circle and appended on the wheel rim, is produced on the light-sensitive layer of the video camera tube;

b. the large and small diameters of the ellipse as well as the spatial position of the diameters and their point of intersection are determined by evaluating the image signal of the video camera tube electronically;

c. different elliptical images of the circle are produced consecutively for the same wheel position and optionally for a different wheel position and the image respectively generated is evaluated electronically;

d. the spatial positions of the wheel plane and of the steering axle and, from the appropriate data as well as the stored positional data of the video camera tube and the wheel dimensions, the wheel axle and steering geometry data are determined electronically on the basis of consecutively obtained measurement results, taking into consideration known mathematical relationships.

The invention starts out from the consideration that the wheel plane of the wheel, which is to be measured, circumscribes the surface of a cylinder, a cone or a rotational hyperboloid, depending on the position of the steering axle during a steering motion and that the large diameter of the elliptical image of the circle assigned to the wheel rim diameter in each case forms a surface line of or a tangent to the body of rotation. Because of the conical section geometry as well as the circle-ellipse affinity, the axis of the body of rotation and, with that, the spatial axis of the wheel suspension, that is, the steering axis as well as the spatial position of the wheel plane, can be determined from the different positions of the wheel and the data of the wheel axles and the steering geometry calculated from the mutual allocation or the allocation to the vertical or horizontal reference planes.

c) Advantages

The special advantage of the new method of measuring lies therein that expensive adjusting work is not required for carrying out the measurement, that the vehicle need not be positioned exactly, that, in principle, there is no need to mount accessories on the vehicle and that all desired values can be determined, indicated and stored by means of electronic equipment.

d) Further Refinements

Advisably, use is made of the known arrangement for carrying out the new method of measuring. For the known arrangement, a video camera is disposed at the side of the longitudinal axis of a vehicle and the electrical parts of the video camera are connected electrically with an electronic image evaluator. To adapt this arrangement to the new method, provisions are made in a further development of the invention that, on each side of the motor vehicle, a video camera is disposed, which can be pivoted in the horizontal direction and shifted

in the vertical direction and the optical axis of which encloses an angle of about 45° or more with the respective wheel axis upon projection into a horizontal plane.

The pivotable and movable arrangement of the video camera ensures that the same wheel position can be detected from two different viewing angles of the camera and that in each case only one camera is required on each side of the vehicle for observing the rear wheel and the front wheel. The geometric arrangement of the camera to the vehicle at the same time ensures that the circle of the respective wheel, allocated to the wheel rim diameter, is imaged as an ellipse on the video camera tube, the accuracy of the detection of the data of the ellipse increasing with the angle formed between the optical axis of the video camera and the wheel axis.

Said arrangement with a pivotable and movable video camera on each side of the vehicle can be modified by providing, instead of a video camera movable in the vertical direction, two video cameras, the position of which is fixed in the vertical direction. In the same manner, the intended pivoting of the video camera, which is necessary in order to be able to detect the front wheel and the rear wheel, can be replaced by two cameras, the position of which in the horizontal direction is fixed. Accordingly, if both measures are to be realized jointly, four video cameras, two of which are allocated to a front wheel and two to a rear wheel, can be disposed on each side of the vehicle.

However, the spatial arrangement of each video camera on one side of a vehicle and its spatial allocation to a front wheel and a rear wheel can also be selected in such a manner, that one video camera with a deflection mirror, movable in the optical axis of the camera, or with two deflection mirrors disposed consecutively in the optical axis of the camera, is disposed on each side of the vehicle, it being possible to swing the mirror, which is close to the camera, out of the optical axis, and that the deflection mirror or mirrors can be rotated individually or jointly in such a manner about the optical axis of the video camera, that the optical axis of the video camera, reflected by the deflection mirror, encloses an angle of about 45° or more with the wheel axis upon projection into a horizontal plane. In this case, the changeover from observing the front wheel to observing the rear wheel is accomplished by swiveling the deflection mirror or mirrors assigned to the video camera, optionally jointly with the video camera, while the displaceability of the video camera in the vertical direction is simulated with the help of the deflection mirrors, which can either be shifted in height or are disposed at different heights. The

mirror of the video camera, which is close to the camera, provides a different picture of the wheel under observation than does the mirror that is remote from the camera.

In the case of such a development of the video camera with one or two deflection mirrors, it may be of advantage for improving the results and properties of the measurements if the camera, together with the deflection mirrors, can be rotated stepwise through a small angle, for example, through an angle of about 1°, about the optical axis of the camera. Independently of this, it may optionally be advisable that the deflection angle of the deflection mirror can be adjusted stepwise by a small angle, for example, by an angle of about 1°.

One or more video cameras can be disposed at the side of the longitudinal axis of a motor vehicle in such a manner, that the front and rear wheels are viewed together from the front or the rear. However, this has the disadvantage that the distance between the video camera and the front wheel is not the same as the distance between the video camera and the rear wheel. It is therefore advantageous to dispose the video camera or cameras on each side of the motor vehicle about half way between the front axle and the rear axle. The elliptical images of front and rear wheels are then approximately equal in size.

When the new method of measurement is used, it may furthermore be of advantage if only a portion of the elliptical image of a circle assigned to the wheel rim diameter and not the complete elliptical image is observed and measured. For this purpose, it is advisable to provide the respective video camera with automatically exchangeable lenses of different focal length or with a zoom lens. With respect to the accuracy of the measurement, it may also be of advantage to provide the respective video camera and/or the deflection mirror with a fine adjustment mechanism, which acts in a horizontal or vertical plane.

Within the scope of the invention, a method of measuring, for which the respective wheel is illuminated line-by-line with a laser beam, the reflected light received and the received light signal, together with the pulses controlling the laser beam, are evaluated electronically, is regarded as a technically equivalent solution. In the case of an appropriate arrangement for carrying out this equivalent method of measuring, each video camera would be replaced by a laser tube with a laser beam deflection system and a light-sensitive diode, which is directed towards the respective wheel.

e) Example

The new method of measuring is explained in greater detail by means of the examples of an arrangement for carrying out the method, shown in Figures 1 to 3, as well as by means of the diagrams shown in Figures 4 to 7.

Figure 1 shows a diagrammatic representation of the chassis of a motor vehicle, on the front axle of which the front wheels 1 and 2 and on the rear axle of which the wheels 3 and 4 are disposed. The steering 5 is provided at the front axle.

On each side of the motor vehicle, approximately half-way between the front and rear axles, a video camera 7 or 8 is disposed, which can be swiveled in the horizontal direction through an angle α, in order to be able to observe the front wheel 1 or 2 as well as the rear wheel 3 or 4 from two different positions. For purpose of observation, the circle 6 of each wheel, assigned to the wheel rim diameter, is emphasized especially. The respective circle is observed by the camera 7 or 8 from two different positions. For this purpose, the video camera can be shifted in the vertical direction by the distance h, as shown in Figure 2. Because of the different height positions of the video camera 8 or 8', the distance between the video camera and the respective wheel or center point of the circle 6 can be determined.

The video camera 7 or 8 is disposed in such a manner that its optical axis and the respective wheel axle enclose an angle β of about 45° in the straight-ahead position of the wheels. When the inventive method of measuring is being carried out, the wheel position of the steered wheels, that is, the front wheels, can optionally be changed several times. At the same time, the angle β is also changed, depending on the magnitude of the angle of turn.

In the case of the example, shown in Figures 1 and 2, the video cameras 7 and 8 can be pivoted and shifted in the vertical direction. This ability to pivot and shift can be switched off if each wheel is observed with the help of two cameras disposed one above the other.

In the case of the example shown in Figure 3, the wheel 4 is observed by means of a video camera 9, which is disposed in a stationary fashion in the housing 10 and the optical axis of which runs vertically from top to bottom. In order to generate an elliptical image of the wheel rim diameter 6, which is not shown in detail, on the light-sensitive layer of the video camera tubes, deflection mirrors 11 and 12 have been provided, which are disposed consecutively in the optical axis of the video camera 9. Moreover, the deflection mirror 11, closer to the camera, can be swung out of the optical axis. In this manner, the wheel 4 can be observed from two different

heights either over deflection mirror 11 or over deflection mirror 12. In order to be able to observe also the front wheel 2 of the chassis shown in Figure 1 with the help of the arrangement shown, the deflection mirrors 11 and 12 are disposed in the frame 13, which can be rotated about the optical axis of the video camera 9. Advisably, the video camera is turned along with the deflection mirrors.

Figure 4 shows the elliptical image 6' of the wheel rim diameter circle 6 of a wheel on the screen 14 of a video electronic picture-reproducing tube. With the help of electronic evaluation of the video signals, for example, five random points of the elliptical image can be selected and their position in an x-y coordinate system determined. On the basis of the coordinates of these five points, the diameter of the ellipse and, with that, the position of the center can be determined.

When determining the characteristic data of the elliptic image, the procedure of Figure 5 can also be employed, according to which only two points and two tangents are determined from the elliptical image 6'' of a circle on the screen 15 assigned to the wheel rim diameter. Starting out from the coordinates of the two points on the ellipse as well as from the equations of the two tangents, which in this case run horizontally, the large and small diameter of the ellipse, as well as the center of the latter, can also be determined.

Figure 6, together with Figure 7, shows an example of how, by means of different lenses, a single image point of the elliptical image 6'' from the large image 15 can be reproduced on an enlarged scale in the image section 16 and, with that, measured more accurately. In order to be able to carry out such sectional analyses, it is necessary to equip the particular video camera with automatically exchangeable lenses of different focal length or with a zoom lens.